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A Harmless Anæsthetic,

OR A

VIRULENT POISON?

BY

Prof. HENRY MORTON, Ph. D.,

President of Stevens Institute of Technology. Hoboken N. J.

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Is It a Harmless Anæsthetic or a Virulent Poison?

[By Henry Morton, Ph.D., President of the Stevens Inst. of Technology.]

In reply to questions put to me on the subject some time since, I stated that carbonic oxide, according to the opinion of the standard writers, was undoubtedly a virulent poison; and, therefore, that this gas was a very objectionable constituent in any mixture which was to be distributed for illuminating or other purposes.

Since the publication of this statement of mine I have noticed that there have been published, in various journals, or printed and circulated, various statements which, more or less indirectly, seem to call in question the soundness of my views on this subject.

As, after all, this is simply a question of fact, on which any one, with the data before him, is competent to form a judgment, I have thought it worth while to compile all the statements by standard authors which were in my reach, and so let them speak for themselves. Whether or not such a gas, as will be there found described, should be considered a "virulent poison," and would be "objectionable," may then be left to the reader for decision, with his common sense for a sufficient guide.

Following a general chronological order in the succession of quotations, I find as follows:

Murray's Chemistry, Edinburgh, 1809, Vol. II., p. 546. Under "carbonic oxide," he says: "It is fatal to life when inspired."

Cutbush's Chemistry, Philadelphia, 1813, Vol. I., p. 126. Under "carbonic oxide." "*Experiment* 4. If a *mouse*, or other small animal be immersed in a jar of this gas, it will destroy it in a short time. *Remark.* This gas is, therefore, deleterious to animal life. When respired for a few minutes it produced giddiness and fainting."

Gorham's Chemistry, 1819, Vol. I., p. 380. Under the heading "carbonic oxide." "It is incapable of supporting combustion, and is fatal to animal life. Sir H. Davy once took three inspirations of it mixed with about one-fourth of common air; the effect was a temporary loss of sensation which was succeeded by giddiness, sickness and acute pains in different parts of the body, and extreme debility. Some days elapsed before he entirely recovered."

Brande's Chemistry, London, 1821, Vol. I., p. 120. Under "carbonic oxide," he says: "It is fatal to animals." Of carbonic acid he says only (p. 429) "It is irrespirable."

Ure's Dictionary of Chemistry, 1821. Article, "'Carbonic oxide' when inspired is fatal to animal life." The account of Sir H. Davy follows, and then: "Since then Mr. Wilter, of Dublin, was struck down in an apoplectic condition by breathing this gas, but he was speedily restored by the inhalation of oxygen."

Parkes' Chemical Catechism, N. Y., 1818, p. 406. Under "carbonic oxide." "It is a gas that will not itself support combustion, neither is it fit for animal respiration. According to some French chemists, birds drop down dead immediately on being put in this gas. These chemists attempted to breathe it themselves; but it produced giddiness and faintness.—*Annales de Chimie*, T. xxxix, p. 56."

Henry's Chemistry, London, 1823, Vol. I., p. 347. Under "carbonic oxide." "It is extremely noxious to animals; and fatal to them if confined in it."

Webster's Chemistry, Boston, 1828, p. 203. Under "carbonic oxide." "It is extremely noxious to animals; and fatal to them if confined in it. When respired for a few minutes, it produces giddiness and fainting."

Thompson's Chemistry, London, 1831, Vol. I., p. 168. Under "carbonic oxide." "No animal can breathe it; when the attempt is made one or two inhalations occasion asphyxia. All gases containing carbon have been found positively injurious when drawn into the lungs."

Thenard's Chemistry, Paris, 1834, T. I., p. 274. Under "carbonic oxide." "It kills immediately the animals who breathe it."

Berzelius' Chemistry, Paris, 1838, T. I., p. 222. Under "carbonic oxide." "Animals die immediately in carbonic oxide gas, and persons who have tried to breathe it have fallen down unconscious."

Daniel's Chemistry, London, 1843, p. 356. Under "carbonic oxide." "It is speedily fatal to animals."

Turner's Chemistry, London, 1847, p. 232. Under "carbonic oxide gas." "It cannot support respiration. It acts injuriously on the system, for, if diluted with air and taken into the lungs, it very soon occasions headache and other unpleasant feelings, and when breathed pure it almost immediately causes profound coma."

Graham's Chemistry, London, 1850, Vol. I., p.

370. Under "carbonic oxide." "It is very fatal to animals, and when inspired in a pure state almost immediately produces profound coma." Of carbonic acid he says simply (p. 364), it "does not support animal life."

Encyclopedia of Chemistry, by Booth and Morfit, Philadelphia, 1850, p. 418. Under "carbonic oxide." "No animal can breathe it, and it is more poisonous than carbonic acid."

Gmelin's Chemistry, London, 1849, Vol. II., p. 89. Under "carbonic oxide." "Small animals immersed in it die instantly. When inspired it produces giddiness and fainting fits. (Clement and Desormes), even mixed with a fourth its bulk of air (H. Davy); it is much more poisonous than carbonic acid."

Regnault's Chemistry, Philadelphia, 1852, Vol. I., p. 321. "'Oxide of carbon' is not merely passive in not supporting respiration, but is active as a poison; for an animal perishes if left for some time in an atmosphere containing a few per cent. of this gas.

"To its presence must be attributed the uneasiness and headache experienced by remaining in a badly-ventilated apartment, near a furnace containing burning charcoal, the products of which do not immediately pass up the chimney. If a large proportion of carbonic oxide gas be present in a closely shut room death ensues from asphyxia."

Chenot. Article in the Comptes Rendus of the French Academy, 1854, p. 735, "On pure carbonic oxide considered as a poison."

In this article its author describes the action of carbonic oxide in such terms as the following:

"The pure carbonic oxide is not simply a reducing agent of the greatest energy, but a frightful poison (*un poison foudroyant*) in very small dose. Finally it appears that poisoning by carbonic oxide is the most terrible in itself and brings after it profound disorganization." This author speaks from his own experience, having suffered several times very seriously from accidental inhalations of small quantities of this gas. In a continuation of this same subject, at a subsequent date, (see p. 830 of the same volume) M. Chenot relates a number of facts which had been brought to his notice illustrating the dangerous properties of carbonic oxide even when mingled with air.

Payen's Industrial Chemistry, Paris, 1859, T. I., p. 93, Foot note. "(*) The production of 'carbonic oxide,' in consequence of an insufficient quantity of air (or oxygen) during combustion, occasions great danger to the health of the workmen, if this poisonous gas is mingled with the air which they breathe."

Stockhardt's Chemistry, Philadelphia, 1861, p. 100. "CO, 'carbonic oxide' is extremely poisonous when inhaled, and constitutes what the miners call coal gas. * * * Notwithstanding repeated warnings accidents not seldom occur from the fumes of burning charcoal."

Lorme's Chemistry. Paris, 1861, T. I., p. 318. *Note.* "The gas 'carbonic oxide' is produced in large quantity when carbon burns in an insufficient quantity of air. It is this which sometimes happens in our rooms. It is especially to the presence of this gas that we should attribute asphyxia from coal, and not to carbonic acid. There is great danger in breathing air which contains some hundredths of carbonic oxide; this gas acts as a pure poison, thus to escape the deleterious influences which it exercises on the constitution it is necessary to ventilate thoroughly the rooms in which carbon is burned."

Chemical News. Article by H. Letheby, Prof. of Chem. and Toxicology in the Medical College of the London Hospital, Apr. 19, 1862, p. 212. "'Carbonic oxide' was discovered by Priestley long before the close of the last century; and in 1802, Clement and Desormes, at the instance of Guyton Morveau, undertook a careful examination of its properties. They not only proved its chemical nature, but they also ascertained that it was a poisonous gas. Birds put into it dropped dead before they could be taken out; and when the experimenters themselves attempted to breathe it, they were attacked with giddiness and faintness.*

* * * "Later still, in 1814, the two assistants of Mr. Higgins, of Dublin, made experiments with it upon themselves, and in one case, that of Mr. Wilter, with almost a fatal result. Having exhausted the lungs of air, he inhaled the pure gas three or four times, and was suddenly deprived of sense and volition; he fell upon the floor, and continued in a state of perfect insensibility, resembling apoplexy, and with a pulse nearly extinct. Various restorative means were employed, but without success, until they resorted to the use of oxygen, which was forced into his lungs, and then his life was restored; but he was affected with violent convulsive agitation of the body for the rest of the day. He suffered also from violent headache, stupor,

* The original article by Desormes and Clement will be found in the Annales de Chimie, Vol. 39, p. 26. The passage here quoted is on page 56.—H. M.

and a quick, irregular pulse. Even after mental recovery he suffered from giddiness, blindness, nausea, alternate heats and chills, and irresistible sleep. The other gentleman, after inhaling the gas two or three times, was seized with giddiness, tremor, and incipient insensibility. These effects were followed by languor, weakness, and headache of some hours' duration.

"Since those experiments were made, others of a more extended character were instituted by Tourdes and by Leblanc. Tourdes found that rabbits were killed in seven minutes when they were put into a mixture of one part of the gas with seven of atmospheric air. A fifteenth part of the gas in common air killed them in twenty-three minutes; and a thirtieth part in thirty-seven minutes. Leblanc's experiments were made in conjunction with Dumas, and he ascertained that one per cent. of the gas in atmospheric air would kill a small dog in a minute and a-half, and that birds were killed immediately in a mixture containing five per cent. of it.

"Very recently I have myself ascertained that air containing only 0·5 per cent. of the gas will kill small birds in about three minutes; and that a mixture containing one per cent. of the gas will kill in about half this time. An atmosphere having two per cent. of the gas will render a guinea-pig insensible in two minutes; and in all these cases the effects are the same. The animals show no sign of pain; they fall insensible, and either die at once with a slight flutter—hardly amounting to convulsion—or they gradually sleep away as if in profound coma. * * *

"Accident has also demonstrated how injurious the gas is even to the human subject. For many years past attempts have been made to promote the use of water-gas as an agent of illumination The gas sometimes contains as much as thirty-four per cent. of carbonic oxide. It is obtained by passing steam over red-hot charcoal; and as the steam is decomposed by the ignited carbon, the hydrogen is set free, and carbonic oxide, with carbonic acid, is produced. Patents for this process of manufacturing gas date as far back as the year 1810, and they have at various times been put into operation in this country and on the Continent. Selligue, in 1840, obtained permission to use the gas in the towns of Dijon, Strasburg, Antwerp, and two of the faubourgs of Paris and Lyons. At Strasburg an accident occurred which put a stop to its use. The gas escaped from the pipes into a baker's shop, and was fatal to several persons; and not long after an æronaut, named Delcourt, incautiously used the gas for inflating his balloon. He was made insensible in the car; and those who approached the balloon to give him assistance fainted and fell likewise. The use of the gas, therefore, has been interdicted on the Continent."

Reissig. Munich. Handbook of wood and peat illuminating gas manufacture, Munich, 1863, p. 59. Speaking of wood gas especially, he says that its inhalation may produce death.

"This latter gas, in particular, is dangerous on account of its large contents of carbonic oxide. Hydrogen, and light carburetted hydrogen, can be much more readily respired without injurious consequences; but not so carbonic oxide.

"The poisonous effects of this gas are known. Every year the lives of many are sacrificed to it, persons who are suffocated by the so-called charcoal fumes, *i. e.*, carbonic oxide.

"Great caution, therefore, should be used, and the main cock should be turned every evening by some reliable person, so that only small quantities of the gas can escape."

Bloxam's Chemistry, London, 1868, p. 78. "'Carbonic oxide' is a gas of so poisonous a character that, according to Leblanc, one volume of it diffused through 100 volumes of air totally unfits it to sustain life; and it appears that the lamentable accidents which too frequently occur from burning charcoal or coke, in braziers and chafing-dishes, in close rooms, result from the poisonous effects of the small quantity of carbonic oxide which is produced, and escapes combustion, since the amount of carbonic acid thus diffused through the air is not sufficient in many cases to account for the fatal results."

Fowne's Chemistry, Philadelphia, 1869, p. 168. Under "carbonic oxide." "It is colorless, has very little odor, and is extremely poisonous—much more so than carbon dioxide."

The peculiar red color of the blood observed in the bodies of those poisoned by carbonic oxide long after death, was noticed at a very early period (at least prior to 1850), and in 1865 an elaborate investigation was published, by Hoppe-Seyler, in the *Zeitschrift fur Analyt. Chemie*, V. III., p. 439. A good abstract of this will be found in the Philosophical Magazine, IV. Series, Vol. XXX., p. 456.

It is entitled "On the detection of poisoning by carbonic oxide." and shows how the changes in the blood, produced by this poison, can be recognized by the spectroscope even after many days.

Miller's Chemistry, London, 1867, Vol. II., p. 72. Under "carbonic oxide." "When respired, even though largely diluted with air, it acts as a direct poison, producing a peculiar sensation of oppression and tightness of the head."

Duflos' Handbuch der angewandten Chemie, Leipzig, 1873, p. 36. "A contents of one-fourth per cent. of carbonic oxide in air gives it the above-mentioned injurious action (dizziness, vomiting, fainting, and finally death), and even with a much smaller amount in a prolonged exposure to such an atmosphere, health may be very seriously endangered."

Hasselt. Handbuch der Giftlehre für Chemiker, etc., 1862. In Vol. II., on p. 352, says—

"'Carbonic oxide' has been found to be a most active narcotic poison for man. The poisonous effects of coal gas are probably due to this.

Hermann. Lehrbuch der experimentalen Toxikologie. 1874, Berlin. "Warm blooded animals soon die in an atmosphere containing carbonic oxide; even very small quantities down to one per cent. are sufficient."

Bernard. Leçons sur les effets des substances toxiques. Paris, 1856. This author says—

"Carbonic oxide is one of the most poisonous gases known."

Eliot & Storer's Chemistry, New York, 1871, p. 338. Under "carbonic oxide." "It extinguishes combustion just as hydrogen does, and destroys animal life. Unlike hydrogen and nitrogen, however, it is a true poison. It destroys life, not negatively by mere suffocation or exclusion of oxygen, but by direct noxious action. Even when largely diluted with air it is still poisonous, producing giddiness, insensibility, and, finally, death. It is the presence of this gas which occasions the peculiar sense of oppression and headache which is experienced in rooms in which the products of combustion have escaped from fires of charcoal or anthracite. Carbonic oxide is very much more poisonous than carbonic acid. Much of the ill repute which attaches to carbonic acid really belongs to carbonic oxide; for since both these gases are produced by burning charcoal, many persons are liable to confound them; but carbonic acid is comparatively speaking almost innocuous. Carbonic acid, it is true, is somewhat poisonous; it does not merely suffocate like water, or nitrogen, or hydrogen; but it is very much less poisonous than carbonic oxide. It has been found by experiment that an atmosphere containing only 1-100th of carbonic oxide is as fatal to a bird as one containing 1-25th part of carbonic acid."

Barker's Chemistry, New Haven, 1870, p. 237. Under "carbonic oxide." "It is totally irrespirable, being an active narcotic poison. one per cent. in the air proving fatal."

Wagner's Jahresbericht, 1874, p. 988. Under "carbonic oxide. "The presence of this poisonous gas was at first, and that justly, urged agains the application of water-gas, it has, however, been found that at higher temperatures carbonic oxide may be oxidized by means of steam into carbonic acid, so that by employing an excess of steam a gas comparatively free from carbonic oxide can be obtained."

Cooke's Chemical Philosophy, Cambridge, 1875, p. 462. Under "carbonic oxide." "The gas is devoid of odor or taste, is very poisonous, etc."

Schorlemmer, Chemistry of Carbon Compounds. London, 1874, p. 63. Under "carbonic oxide.' It is but sparingly soluble in water, and acts as a strong poison, producing death when inhaled even in small quantities."

In the Annales de Chimie et de Physique, 1842. Third Series, Vol. V. pp. 223–268, we find a long article, by M. F. Leblanc, under the title —"Recherches sur la composition de l'air confiné." In this extensive treatise, covering some 45 pages, the author, after describing experiments in which it was proved that the actual products of the combustion of a candle, or of charcoal, were far more poisonous than pure carbonic acid mingled with air continues as follows:

"Althongh the opinion generally received did not appear to attribute to carbonic oxide, especially when present in small quantity, a deleterious action on the animal economy, I wished to ascertain by precise experiments the part of the influence it could exercise in the effects of the combustion of charcoal. I studied at the same time the action of the gases proto and bicarburetted hydrogen.

"Regarding these latter products, experiment shows that they cannot have an active part in the asphyxiating effects of charcoal. The gas protocarburetted hydrogen obtained from acetates, and oleflant gas, can be mixed with air, in the proportion of one to two hundredths, without causing any apparent accidents, even at the end of a considerable time. Such is not the case with carbonic oxide. A dose of four to five parts in a hundred of air caused the instant death of a sparrow. A hundredth part of this gas mixed with air killed a bird at the end of two minutes.

"If the animal is immediately removed from this deleterious influence at the moment of apparent death, it can little by little regain life; but it is often only after some hours that the phenomena of paralyzation disappear.

"We must, therefore, look upon carbonic oxide as a gas eminently deleterious, contrary to the conclusions of Nysten, who had placed this compound among the simply irrespirable gases. This latter opinion besides has not been adopted by M. Devergie, in his new Traité de Médicine Légale, and in his excellent article on the gases, (Dictionnaire de Médecine et de Chirurgie pratiques). Observing that the injection of carbonic oxide into the veins, according to Nysten's experiments, caused the animals to utter cries of pain, and relying moreover on the effects experienced by Samuel Witte (1) after a few inspirations of this gas, M. Devergie does not hesitate to place carbonic oxide among the deleterious gases (2).

"According to the facts here given we are led to admit that carbonic oxide habitually plays the principal part in the deleterious effects produced by the combustion of charcoal."

And further on, p. 246:

"We have pointed out that the toxical property of an asphyxiating atmosphere under these influences should be attributed more particularly to the presence of carbonic oxide ascertained by analysis, since, even when diffused in air to the extent of one part in 100, it forms an atmosphere almost immediately fatal to warm blooded animals; the observed proportions of carbonic acid present, and of oxygen wanting, would not produce nearly such violent effects. It is, therefore, necessary to point out without delay the dangers which may result from the accidental presence of carbonic oxide in air, dangers to which, as far as I know, our attention has not yet been sufficiently called, especially to the influence of such small quantities."

So far we have given quotations expressing the general literature of this subject; now we will turn to the special departments which concern themselves with such substances as we consider "carbonic oxide" to be—namely, Toxicology, the science of the detection and counteraction of poisons; Hygiene, the science of preserving life and health from destructive agencies.

In Werker's "Lehrbuch der praktischen Toxicologie," Erlangen, 1869, p. 81, we find as follows:

"Although pure carbonic oxide possesses but little interest in practical toxicology, it has become a matter of great importance on account of the continually increasing number of accidents resulting from charcoal fumes and illuminating gas, in which carbonic oxide occurs mixed with other gases, and of which it forms the specially poisonous constituent. The symptoms, altogether similar, and the condition of the body after death prove conclusively the truth of this latter opinion, although it will not be denied that other admixtures, carbonic acid for instance, may have some effect. Poisoning with pure carbonic oxide can only occur from the careless performance of chemical or physical experiments.

"The gases resulting from the reduction of many metals, (zinc furnaces, etc.), are always more or less mixed with carbonic acid, and resemble charcoal fumes. Three to five per cent. of carbonic oxide mixed with air kills dogs and cats in three to five minutes, birds are specially sensitive, invertebrate animals very little. * *

"The gases resulting from glowing charcoal, coal or peat contain on an average 2.54 per cent. of carbonic oxide and 24 per cent. of carbonic acid.

"Poisoning from charcoal fumes is especially frequent in France. Statistics show that of the 17,852 suicides, occurring in the years 1848–52, 1,401 were from charcoal fumes, and 411 from other poisons.

"That the poisonous character of charcoal fumes is due to carbonic oxide, is proved by the fact that their poisonous nature is retained after removing the carbonic acid by lime water.

"Illuminating gas which, as is well known, is produced by the dry distillation of coal or wood, and lately, also, of petroleum, varies very much in composition, according to the material employed, the heat applied, and the more or less perfect purification. * * *

"Marsh gas, like hydrogen, is only irrespirable, but not poisonous. In the case of olefiant gas this is not absolutely established, for, according to some observers, it is said to produce a slight giddiness. Its effect is certainly a very slight one, and on account of the small quantity found in the gas it has probably no influence. We must then consider carbonic oxide as the poisonous principle."

Numerous other statements, similar in effect, are found in the same work; but to quote them all would occupy too much space, and would not add to the force of what we have already transcribed.

Turning next to "Eulenberg's Handbuch der

Gewerbe-Hygiene," Berlin, 1876, p. 344, we find as follows :

"The effects of carbonic oxide agree with those of carbonic acid only in so far that, with small quantities, there may also be decided symptoms of irritation, which, however, far more rapidly than in the case of carbonic acid, pass into general prostration." Then, after enumerating at length the preliminary symptoms, he continues :

"If help is not rapidly rendered there follows prostration, with somnolency, enlargement of the pupils, cold perspiration, coldness, loss of feeling in the skin, relaxation of the muscles, difficult breathing, slow pulse, and then death rapidly follows."

On page 347 the author gives a series of experiments on doves and rabbits, with mixtures containing carbonic oxide and carbonic acid mingled with air, in various proportions, from ¼ p. c. to 3½ p. c., and then says in conclusion :

"We see, from these experiments, that a slight increase of the amount of carbonic oxide produces, altogether independently of the larger or smaller amount of carbonic acid, the characteristic symptoms of charcoal fume poisoning. Might not the *prolonged* action of *small quantities of this gascous mixture* be of importance in the production of pulmonary affections?"

On page 352, the same author says : "For sanitary reasons, on account of the very poisonous properties of carbonic oxide, all processes in which this gas is produced should be very strictly watched."

On page 603, he says : "In the case of illuminating gas, the most dangerous cases are those in which poisonings occur in houses where no gas is consumed, and where it has entered only in consequence of leaks from mains in the streets."

"Remarkable cases of this kind, which were mistaken even by physicians for typhoid cases, have been described by Pettenkofer. "Die Beziehung der Luft zur Wohnung, etc., p. 87." "Relations of air to our dwellings."

M. G. Tourdes, whom we shall have occasion to quote presently in another connection, has published a pamphlet entitled "Rélation Médicale des Asphyxies occasioneés à Strasburg par le Gaz de l'éclairage."

The incident here related and discussed was the poisoning (resulting fatally in several cases) of an entire family, caused by a leak from a pipe conveying water-gas.*

Devergie, in his Médecine Légale, Paris, 1852, Vol. III., p. 82, after quoting the experiments of Nysten on men and animals, says :

"These experiments plainly show the deleterious action of carbonic oxide, and the following, which was made and reported by Samuel Witte, (Bibl. brit. sc. et arts, LXI.) leaves no doubt in this regard." He then describes the experiment, at the end of which he says: "The usual methods resorted to in cases of asphyxia remained without avail. He was then treated with oxygen gas, which brought him back to life."

On turning next to the immense work which bears the modest title—"A handy book of Forensic Medecine and Toxicology," by Woodman and Tiely, London, 1877, we find, on page 557, as follows ;

"Carbonic oxide, when respired passes freely into the lungs, as much as 4 per cent. being found in the blood of animals exposed for from 10 to 25 seconds to an atmosphere containing 10 per cent. of this gas. When absorbed by the blood it combines with the haemoglobin. * * *

* * "Tho poisonous action of carbonic oxide was noticed by Guyton Morveau, in 1802, and by Sir H. Davy, in 1810." * * *

* * "Mr. Higgins, of Dnblin, Tourdes, Leblanc, and Letheby, have also experimented with it. Tourdes proved that one part of gas ni seven of air, killed rabbits in seven minutes—one in fifteen, in twenty-three minutes—and one in 30 in 37 minutes."

"Leblanc and Dumas' experiments show that air containing one per cent. of the gas will kill a dog in one and a-half minutes, and that birds die instantly in an atmosphere containing five per cent. Dr. Letheby found in his experiments that air containing ½ per cent. of the gas kills small birds in about 3 minutes ; whilst if it contains one per cent., it proves fatal in about half the time. An atmosphere containing two per cent. rendered a guinea-pig insensible in two minutes. There were no signs of pain—but the animals fell down insensible, and died at once, either with a slight flutter, hardly amounting to convulsion, or gradually slept to death, as if affected with a profound coma. Carbonic oxide is in short a pure narcotic poison. * * * *

"The large quantity of carbonic oxide in water gas (often 34 per cent.) would render its employment dangerous as an agent of illumination." *

* *

On page 557 of the same work we find as follows ;

"In London gas the amount of carbonic oxide varies from five to seven per cent. ; light carbu-

* See quotation from Letheby above.

retted hydrogen, 40 to 45 per cent. ; and olefiant gas, three to four per cent. There is little doubt that carbonic oxide is the most actively poisonous of the gases present.

"Indeed some have stated that it is the only poisonous body, (M. Tourdes). But it is more than probable, as Dr. Taylor suggests, that the various hydrocarbons present have also a noxious influence. It is curious, however, that in a very dilute state, *pure* carburetted hydrogen does not appear dangerous to health, inasmuch as the miners breathe it continually without any apparent ill effects resulting."

The various quotations given thus far make it, we think, abundantly manifest that, in the opinion of the standard writers on chemistry, as expressed in their publications, "carbonic oxide" is one of the most virulent and dangerous gas poisons, the presence of which even to the extent of a few per cent. in the air of a room renders it utterly unfit for breathing and often even fatal.

In face of this, however, we have the fact that certain authors have made experiments with this gas *as an anæsthetic*, and have written papers about it in this character, and have compared its effects with those of chloroform and other anæsthetics ; and have even given it, in some of their statements, a preference to chloroform as an anæsthetic agent.

Now this statement of the case, which, moreover, is *literally correct*, would certainly convey the impression that the dangerous properties, as stated by the authors whom we have quoted, had been overestimated or exaggerated.

Before forming a judgment, however, it will be safest for us to refer to the original publications of these gentlemen, and see for ourselves exactly what they *do* say on the subject.

Thus, in the first place, we have an article *On the anæsthetic action of gases.—Carbonic Oxide*, by Dr. Ozanam, published in the Archives Générales de Médecine, Paris, 1857. 5th Series, Vol. IX., p. 159. This article covers about 20 pages, and we must therefore content ourselves with a few extracts, so selected, however, as to give the character of the whole publication.

In the first place, he announces the theory on which his experiments were based in the following words :

"The more carbon bodies contain, and the more easy their elimination, the stronger must be their anæsthetic property."

Then, after some general remarks, and a description of the method used in preparing the gas, he continues :

"Our experiments and observations amounted to 30 in all, of which 25 were made upon rabbits and five upon men ; among the latter there are two pertaining to Samuel Witte. We cannot give here a full report of all these cases ; it will be quite sufficient to recount in a few words the most important cases.

"A.—*Action of carbonic oxide when inhaled.* The phenomena produced by the inhalation of carbonic oxide naturally divide themselves into four periods :

"Premonitory stage.
"Period of excitement.
"Period of anæsthesia.
"Death or recovery.

"FIRST PERIOD—PREMONITORY STAGE.

"A fine tube screwed to a bladder full of carbonic oxide was introduced into the mouth of a rabbit, firmly held, and whose nostrils had been stopped up ; an assistant pressed on the bladder, and the animal forced to breathe by its mouth, inhaled the gas mixed with atmospheric air.

"During the first five or six inspirations the animal does not make the least effort ; it is motionless, stunned, as if it were under the impression of some danger which it suspected, yet did not know, and of whose violent effect it was not yet conscious.

"I notice this stage, because it contrasts by its calmness with the active effects of a gas so powerful as carbonic oxide.

"SECOND PERIOD—EXCITEMENT.

"But at the end of 15 to 30 seconds the scene changes ; the animal trembles and attempts to escape. Next these voluntary movements are replaced by strong convulsions, various in their form, contractions, turning back of the head, trembling, etc. This lasts from one to four minutes, according to the vigor of the subject, and according as to whether the gas is applied continuously or intermittently. * * *

"THIRD PERIOD—STUPOR

"The convulsive stage is quickly followed by the period of collapsus or stupor. All motion ceases, the body falls down as an inert mass, the head hangs, the eye is wide open, the pupil dilated, sight almost gone, the four limbs paralyzed, the urine flows involuntarily, the heart beats grow slower (from 180, the normal figure, to 100), respiration also grows slower, it falls to 60 to 40,

while in the normal state it is abont 100 respirations per minute.

"If the inhalation is continued, the act of respiration becomes still less frequent; it only occurs every five or ten seconds, by a general and sudden effort resembling hiccongh. But prolonged to this stage the anæsthesia becomes dangerous, and must be closely watched, since the inspiratory nerves are almost paralyzed, and the state of apparent death approached.

"The pulse and the state of the respiration are then the surest guides to be followed in order to regulate the effect of the gas. The less frequent they become the greater the danger.

"All the phenomena jnst described take place in a space of time varyiug from one to six minutes, according as to whether we proceed in a continnous or in an intermittent manner.

"FOURTH PERIOD—RECOVERY OR DEATH.

"A. Recovery.—The inhalation is stopped, the animal left to itself. For one to three minutes the anæsthesia remains complete; oue could believe the animal dead, were it uot that auscultation still reveals the enfeebled beating of the heart and some occasional efforts at respiration. Soon regular life begins agaiu, respiration is reëstablished; the heart gradnally regains its normal figure, and even passes it a little (from 10 to 15 pulsations). At the end of from two to four minutes sensibility returns to the ears, the skin is still insensible. The animal rises to its fore feet; its hindquarters are still paralyzed. At the end of six minutes one can still, in a large majority of cases, run a limb eutirely through with a stylet without causing a sigu of pain. After 8, 10, 14 minutes, according to the subject, and the degree of anæsthesia, the animal returns to its normal state.

"B. Death.—The passage from stupor or apparent death to real death is sudden and unexpected, resembling in this respect suddeu death by chloroform. The heart and respiration, already much enfeebled, are suddenly and forever arrested. In one case death resulted after two minutes inhalation of the gas; but, a thing worthy of remark, in the course of our experiments, a rabbit submitted to chloroforming died in a shorter space of time (1½ min.) * * *

"ACTION OF CARBONIC OXIDE ON MAN.

"Can carbonic oxide be inhaled by man? Everything points to the belief that it can, above all if care be taken at the same time to breathe a certain quantity of atmospheric air. Without doubt extreme caution is necessary; but the 25 experiments which we made, and of which several have been repeated upon the same animal, show that the use of this gas is not so dangerous as was formerly believed, since we have but one case of death among animals so delicate as rabbits.

"As affording valnable insight into this question, we give here from Orfila (Toxicologie, Vol. I., p. 552, 1843), the two experiments made by Samuel Witte, on himself.

"Experiment 1. In the first Samuel Witte experienced convulsive trembling and vertigo, with an almost complete suspensiou of sensibility after two or three inhalations of the gas. Languor, cephalalgia, and a state of weakness, followed these phenomena.

"Experiment 2. In the secoud experiment he almost iustantly fell backwards, deprived of motion, pulse and sensibility, after making 3 or 4 strong inhalations, having first emptied his lungs. The breathing of oxygen gas was followed by better effects.

"He still, however, experienced a convulsive agitation and a very severe headache. It was some time before he recovered sight, and he was a prey to nausea, vertigo, and to alternations of chills and fever. He had finally a great inclination to sleep, which was broken and feverish. (Biblioth. Britann. des Sciences et Arts, T. LXI).

"We notice again in these interesting facts the two periods of excitement and of collapse proper to anæsthesia; the insensibility also, as well as the too violent effects of the gas when it is respired pure, as in the second experiment.

"From this we are justified in concluding that carbonic oxide can, with precaution, be respired by man, that it also produces anæsthesia in this case, and that by mixing atmospheric air with it its strength and effect can be regulated at will."

After this follows a description of experiments on the local application of this gas, and other matter not related to our present subject; but what we have above quoted is every word that this author states in reference to *the action of carbonic oxide on man.*

This, taken in connection with his earlier statement, that—"Our experiments amounted to 30 in all, of which 25 were made upon rabbits and 5 on men; among the latter there are two pertaining to Samuel Witte," is certainly, to say the least, very curious. Of *our* five experiments two are quoted from another writer, and the remaining three are passed over in silence, or were only

local applications of the gas to diseased surfaces. The justice of the conclusions, drawn from such data, may well be questioned by any one who does not, like M. Ozanam, enter upon the subject with a ready-made theory which he desires to support. The facts related by this author are, however, valuable, and give a very different complexion to the subject from that which appears in certain general references to his work which we have not met with, in more than one publication.

Turning next to the Comptes Rendus, 1857, T. XLIV., p. 96, we find an article entitled "Mémoire sur l'action anæsthetique du gaz oxyde de carbone, par M. G. Tourdes."

Here we encounter, near the beginning, a most encouraging phrase, for the author, from whose other publications (pamphlet on the Strasbourg poisonings with water gas), and his experiments, quoted by Woodman and Tidy, we should hardly expect such an opinion, says: "The two fundamental facts are the harmlessness of the gas and its anæsthetic action."

That this is, however, only a careless form of expression very soon appears, for a few paragraphs further he goes on. "When we prolong the action of the gas the animal succumbs. It is necessary to arrest it as soon as the anæsthesia is complete. Death may be sudden, with cries and convulsions; but more frequently it is peaceful. The transition from sleep to death is insensible, respiration is arrested, the carbonic oxide seems to act by paralyzing the muscles of respiration.

* * * "In establishing the anæsthetic action of carbonic oxide, it is a duty to point out at the same time the dangers which result from the gaseous form and difficulty of application of this agent, so as not to take the responsibility of the accidents which will occur one of these days." This seems an unkind way of referring to a "harmless anæsthetic," whose only "difficulty of application" seems to be the trifling one that during its administration "the transition from sleep to death" may be "sudden," or may be "insensible"; but is too probable to make the author willing "to take the responsibility of the accidents which will occur" if it is used.

It would seem, therefore, that even these authors who have been referred to as having proposed and used carbonic oxide safely as an anæsthetic agent, upon man as well as upon lower animals, and who have compared the symptoms to those of chloroform, do not encourage its general application very strongly when they are directly consulted, and fully quoted, but leave us with the same old impression derived from the chemical literature of the subject, that carbonic oxide is a very dangerous gas poison of which we should beware.

It has, however, been said that, granting this, still ordinary coal gas is also a poison, and that the substitution of one poison for another is a matter of no practical moment to the people who fall victims to either, and still less to those who escape both.

Now, in reply to this, we would, in the first place, call attention to the very decided opinion expressed incidentally by some of the authors already quoted, and founded on extended experiments, to the effect that *the only practically poisonous constituent of coal gas is its five to seven per cent. of carbonic oxide.*

Next, we would ask attention to a few other quotations of statements directly bearing on these points.

Thus, Enlenberg in his Handbook of Technical Hygiene (or hygiene in connection with manufacturing processes, etc.), on page 38 declares hydrogen to be perfectly harmless.

Werker, in his Toxicology, does not mention hydrogen at all among poisonous substances.

Miller, in his Chemistry, p. 41, says: "Pure hydrogen, though it cannot support life, is not poisonous; and, when mixed with a certain proportion of air has been breathed for some time without inconvenience."

Such quotations might be indefinitely multiplied, but it is, we presume, accepted on all hands that hydrogen is not a poisonous gas.

Passing next to

MARSH GAS.

Miller, in his Chemistry, Vol. II., p. 236, says that it is "not injurious to life if diluted with air."

Leblanc, in the Ann. de Chim. et de Phys., 3d Series, Vol. V., p. 239, says that marsh gas and olefiant gas are not injurious.

Eulenberg. Handbuch der Gewerbe Hygiene, already mentioned, at p. 368. says: "The action of marsh gas on the animal organism is in no way injurious to health; if headache, dizziness, fainting and similar effects are produced it is certainly mixed with carbonic oxide. In coal mines such mixtures not unfrequently occur. According to the amount of carbonic oxide present, the workmen will be more or less affected with symptoms which never occur with pure marsh gas.

"Rabbits can remain in an atmosphere con-

taining five per cent. of marsh gas for 20 minutes without showing anything abnormal.

"According to Richardson, 70 to 80 per cent. of the gas is necessary to produce an anæsthetic sleep. In experimenting with animals this effect was not observed."

Fowne's Chemistry, Philadelphia, 1869, p. 169. Under marsh gas. "It is not poisonous, and may be respired to a great extent without apparent injury."

Hermann, Berlin, p. 275. "Marsh gas has been proved to be indifferent."

Leblanc. Comptes Rendus, 1842, T. XIV., p. 868. "But some experiments made on animals demonstrated to me that even a very feeble dose of carbonic oxide may occasion very serious, and even fatal accidents.

"Thus, a dose of five per cent. in air will instantly kill a sparrow; a dose of one per cent causes death in two minutes or more. Marsh gas on the contrary, in a dose of one per cent., does not produce any serious effect even in a much greater length of time.

"Olefiant gas diffused in air to the extent of some hundredths does not produce any ill effects."

Hermann, p. 276. "Ethylene gas ($C_2 H_4$), I have proved on myself to be mildly intoxicating, almost like laughing gas."

ETHANE,* ($C_2 H_6$).

Eulenberg, p. 398. This author, after describing four experiments on animals, remarks: "The foregoing experiments prove undoubtedly the anæsthetic action of ethane; in this respect it is the first one of the ethyl compounds known as an anæsthetic. Mixed with a sufficient quantity of air it does no permanent harm, since it does not prevent the blood from absorbing oxygen." This last remark is made in reference to the observation that carbonic oxide seems to produce its fatal effects by entering the blood, to the exclusion of oxygen whose absorption it thus prevents.

From all this it would certainly seem to be very evident that, in the opinion of competent judges and authorities, the constituents of ordinary illuminating gas, other than carbonic oxide, bear no sort of comparison with it in poisonous properties, even if they have any serious ill effect at all.

To sum up then, in a few words, it seems to us that as far as the weight of authority goes, carbonic oxide stands condemned as a rank poison, very exceptionally dangerous as compared with the other constituents of illuminating gas.

This by no means deprives those gentlemen who think differently of their right to their own conclusions; but, on the contrary, tends to establish their claim to originality, and shows that their ideas are exclusively their own, and have not been anticipated by any prior publications.

There still, however, remains another standpoint of observation from which this question, in its practical application to water gas, may be viewed with propriety.

This, I think, I can best express by describing in the first instance a parallel but hypothetical case.

Suppose that the safety-matches, made with amorphous phosphorus, were first invented and introduced, and that the question were then asked about the desirability of introducing "parlor matches."

We might say, "safety matches *may* cause loss of life by fire, or, perhaps, if not made with strict care might be to some degree poisonous; but the parlor matches are much more likely to cause a conflagration and are much more poisonous—shall we, therefore, discourage the parlor match?" Prudence certainly says: don't add to the existing risks to life and property; but a larger range of view might disclose such considerations as these; the risks in either case are very small. Both articles are harmless under normal conditions. The knowledge of danger will make people more careful, etc.

If, then, there is some decided gain to be expected by the public at large from the parlor-match, an enlarged philanthropy may even advise that the additional risk should be run, and "the greatest pleasure of the largest number" secured, even at the cost of a few more houses consumed or children poisoned.

When, therefore, it shall appear that the introduction of water gas is to benefit the world at large, it may well be urged that the benefit is worth what it costs in added risk.

Apropos of the match illustration I have a suggestion of encouragement to those who are engaged in developing the water-gas manufacture, which it gives me great pleasure to make; for I really have no interest on either side, and entertain the most friendly feelings for those engaged in promoting "water-gas." My suggestion is this:

The safety-match was put in the market at least 20 years ago, and yet the inflammatory and

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* We introduce a reference to ethane here, not of course because we regard it as a constituent of coal gas, but to provide for future reference, and to make this class of citations complete.

poisonous "parlor-match" still triumphs, thanks to its superior convenience.

Nitro-glycerine entered the world heralded as it were by a holocaust of some hundreds of human beings, and is still the very type and example of destructive agents; yet, on account of its convenience, economy, and efficiency, it is to-day *the* explosive of the world in all engineering applications. It is also practically less destructive than gunpowder, because, among other things, a sense of its ability to destroy causes it to be handled with caution. The "moral" hardly needs statement. When water-gas is a successful manufacture, its capacity for evil, when misapplied, will neither check its application nor render that application practically safer by being depreciated.

I will take advantage of the present opportunity to correct a mistake of my own, which has only just come to my knowledge. In my report on the Harrisburgh gas, published in this Journal, of Nov. 2d, 1877, I gave the increase in amount of carbonic acid, produced by the combustion of a given volume of that gas, as 70 per cent. greater than that produced by the combustion of an equal volume of ordinary coal gas. On referring recently to my original notes, I find that this 70 should have been 50. The number 70 occured as the result of one of the preliminary calculations, and was accidently copied into my report.

This mistake is one of those which one would believe impossible if they did not occasionally happen.

Fortunately, large as the error is, it does not involve anything affecting the general conclusion reached, whether a water-gas produces 50 or 70 per cent. more carbonic acid than an average coal gas, is simply a question of degree.

One of my critics seems to suppose that the relative quantities of carbonic acid from coal and "water-gas" depend upon the products of combustion of marsh gas and of carbonic oxide. Here he is himself in error.

The large yield of carbonic acid in water-gas comes, not from its containing carbonic oxide as a substitute for marsh gas, but from the large percentage of illuminants which it contains, and which, being rich in carbon, yield excessive amounts of carbonic acid. Thus olefiant gas yields twice as much carbonic acid as marsh gas, and other members of the olefine series progressively, three, four, five, etc., times as much; acetylene twice as much as marsh gas; also, pure benzole, six times as much, and the various members of the paraffine series such amounts as are indicated on page 68 of the present volume.

But it may be suggested, if the illuminants are the cause of this increased yield of carbonic acid, must it not be more than cancelled by the gain in candle power.

This does not, however, follow. The very interesting record of results, by Frankland and Thorne, republished on page 78 of this volume, from the *Chem. News*, shows that where marsh gas is replaced by carbonic oxide, a very much larger proportion of an illuminant is needed to produce the same candle power. This drawback is, therefore, inherent in any gas which replaces marsh gas by carbonic oxide.

It is worthy of note, also, that very rich, or high candle power, coal gas will have a similar drawback, as compared with a poorer one, and will tend to vitiate the air of rooms to a greater degree.

It is no practical answer to this objection to say that, with a higher candle power, less gas is proportion is used. This is not true within the range of moderate variations, such as are now considered (16 to 20 candle power.) The consumer, with a richer gas, rejoices in his superior light, and turns on an extra burner to realize his advantages more thoroughly.

We are not referring to extreme cases, or maintaining that in a nearly pure marsh gas there would be a better condition of affairs in this respect than in a rosin gas; but, simply, that within an ordinary practical range high candle power may not always be an unmixed advantage.

As regards the actual fact of the production of carbonic acid, by coal gas and water-gas on burning, I made the simple experiment of exploding known volumes of coal gas and "water gas", and determining the volumes of carbonic acid actually produced, and of oxygen actually consumed in that operation.

Thus 100 measures of the illuminating gas from coal, supplied by the Hoboken Gas Company, as it comes from the burners in my laboratory, yields 64.945 measures of carbonic acid, while 100 measures of "water-gas," supplied by the Municipal Company of New York, as it comes from a burner in the School of Mines, yields, on combustion, 99.93 parts of carbonic acid.

The amounts of oxygen consumed are about the same, in each case, being in fact—

Hoboken gas 133.375 per 100 vols. of gas.
Municipal gas 151.24 " " "

The reason of this large yield of carbonic acid from water-gas, as I have already stated, is to be

sought not in carbonic oxide, but in the excessive amount of illuminants which water gas *requires* to bring it up to a good standard.

Thus, while a coal gas with 6 per cent. of illuminants will give 16 candle power, a water-gas, with 18 per cent. of illuminants, will only give 22 candles; or, in other words, requires 200 per cent, increase of illuminants for 37 per cent. increase in light. This is necessary, because as Frankland's article, already cited, shows, while marsh gas is not an illuminant, and contributes nothing to the production of light, yet carbonic oxide is a sort of *negative illuminant*, or absorbent of some 20 per cent.

The following analyses of some "water" and coal gases, will show these and some other curious relations.

Analyses of "Municipal gas," made in June, 1877, in which the presence of benzine or paraffines was first noted by me.

Carbonic acid	.21
Oxygen	.14
Benzine vapors & like illuminants	1.14
Olefiant gas and like illuminants.	15.12
Carbonic oxide	26.18
Hydrogen	27.29
Marsh gas	25.43
Nitrogen	4.45
	99.96

In this and other cases I used the popular word "benzine," to indicate, in a general way, a mixture of paraffines, such as the benzine or petroleum naphtha represents. I have since abandoned the use of this word to avoid confusion with benzole, C_6H_6, which is, of course, reckoned in an ordinary analysis among the "olefines, or illuminants." Of course no one supposes that benzole is an "olefine"; but, as for practical purposes, its behavior in an illuminating gas is identical with an olefine, this loose way of indicating the group of bodies absorbed by Nordhausen acid or bromine is not objectionable.

Ordinary Coal-gas.

	Russel.	A. Wurtz		W. D. Thompson.
Carbonic oxide.	4.167	12.9	6.6	5.62
Carbonic acid...	1.950	.3	3.6	.46
Oxygen.....	.139	——	——	H_2O 2.48
"Olefines".....	5.504	3.8	6.4	3.86
Hydrogen.....	45.847	50.2	45.6	45.43
Marsh-gas.....	40.948	32.8	34.9	39.93
Nitrogen.....	1.445	——	2.7	2.22
	100.000	100.0	99.8	100.00

It is a curious circumstance that the water-gas shows less hydrogen, as a rule, than the coal-gas.

Municipal gas, Dec. 12, 1877.

Carbonic acid	.371
Oxygen	1.021
"Olefines"	17.363
Carbonic oxide	27.893
Hydrogen	23.487
Marsh-gas	24.612
Nitrogen	5.235
	99.982

In this analysis the fraction of a per cent. of paraffines was not removed, and the hydrogen and marsh gas members are, therefore, in error to a corresponding amount.

Harrisburgh water-gas, collected January, 1878.

Carbonic acid	3.691
Oxygen	.421
Olefines	12.376
Carbonic oxide	26.190
Hydrogen	31.865
Marsh gas	21.631
Nitrogen	3.788
	99.962

Paraffines not determined in this particular case, and thus hydrogen and marsh gas figures are subject to correction.

I have lately heard my analyses criticised because they did not foot up 100.

This is a matter of taste, however, in which I claim the right of pleasing myself. These determinations involve a considerable amount of calculation. I have carried my figures out in them to the third place of decimals, and neglected all beyond. This causes a slight deficiency in the summation of results. It would be easy enough to "pad" the figures to a round sum, and even if this was all done in one item it would hardly introduce an error equal to that which probably exists from other causes, and would certainly be of no practical importance whatever. For my own part, however, I think that the actual numbers look just as well, and are no less honest than a round sum obtained by making ·286 = ·290, or the like.

Note.—By the term "water-gas" as used throughout this article, of course I intend the illuminating mixture popularly so-called.

Stevens Institute, Hoboken, N. J.
March 2nd, 1878.

Date Due

DUE [illegible]		